J. Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 2 (3): 265 - 277, 2011

USING THIOPAQ SULFUR FOR REDUCING NH_3 VOLATILIZATION FROM CALCAREOUS SOILS AND INCREASING N USE

Mahmoud, Amal H.[*] **and Kh. A. Rateb**
Laboratory of Soil Salinity and Alkalinity Res., Inst. of Soil, Water and Environment Res., Agricultural Research Center, Pakkous, Alexandria.
*** Corresponding author e mail address: amalmattar611@hotmail.com**

ABSTRACT

A laboratory and greenhouse studies were conducted to evaluate the effect of different rates (0.1, 0.5 and 1.0 ton ha^{-1}) of THIOPAQ elemental sulfur (TES) application to the urea amended calcareous soils on NH_3-N volatilization from soil surface and on N uptake efficiency by corn plants. In incubation experiment under laboratory conditions, daily ammonia loss was measured for up to 30 days after surface urea-N applied to soil (200 kg N ha^{-1}) using closed dynamic airflow system. Results showed that daily NH_3-N loss in tested soils were in the order: M. Ismail > Adam > Abu Bakr soils within the first 18 days of incubation then turned to Abu Bakr > Adam > M. Ismail soils until the end of experiment. Total NH_3-N volatilization from urea-treated soils were 50.3, 49.8 and 66.6% of applied N in Abu Bakr, Adam and M. Ismail soils, respectively. Significant reductions in NH_3-N volatilization were observed in urea amended with TES and this reduction increased by increasing applied TES rate. The percentage inhibition in NH_3-N loss as a result of application of different TES to tested soils ranged between 14.60-37.52, 75.28 – 84.52 and 70.00 – 77.42 in Abu Bakr, Adam and M. Ismail soils, respectively. The reduction in NH_3-N loss by TES was accompanied by a decrease in soil pH and increase in concentrations of water soluble SO_4^{2-}. It is concluded that application of TES by rates 0.1 and 0.5 tons ha^{-1} had significant effect in reducing ammonia volatilization from surface applied urea. Results of greenhouse experiment showed that TES application and *T. thiooxidans* inoculation had significant effects on biomass production and N uptake by corn plant. Soil inoculation without addition of S increased N uptake in both shoots and roots by 22.25 and 19.5%, respectively, and reflects the promoting role for bacteria on N uptake. TES application significantly increased N uptake by plant shoots and roots and more uptake was obtained with applied TES and inoculation with *T. thiooxidans*.

Keywords*:* Elemental sulfur, NH_3 volatilization, N use efficiency, zea maize, calcareous soils.

INTRODUCTION

Favorable economics of manufacturing, handling, storage, and transportation have made urea becomes the most widely used form of N fertilizer in the world. World urea supply is estimated at 158.5 Mt in 2009 and 165.2 Mt in 2010 comparing with 152.0 Mt in 2008 (Heffer and Prud'homme, 2009). Although urea has such advantages over other N fertilizers, it also has an important disadvantages in respect of considerable loss of N which can occur if the urea is surface applied to soil. The loss occurs through ammonia volatilization after urea is hydrolyzed at the soil surface by catalyzes of urease enzyme (Byrnes and Freney, 1995) as follow:

$$(NH_2)_2CO + H_2O \rightarrow CO_2 + 2NH_3$$

The NH_3 losses due to urea hydrolysis under field conditions may reach as much as 80% of the total N applied (Gould *et al.*, 1986). The extent of ammonia volatilization losses can be related to a number of soil and environmental factors, including soil pH, cation exchange capacity, H^+ ion buffering capacity, $CaCO_3$ content, soil organic matter content, the amount and type of residue present, urease activity, soil moisture content, temperature, relative humidity, wind speed, rainfall pattern, and N source (Watson *et al.*, 2008 and Nelson, 1982). Although the influence of the individual factors on NH_3 volatilization has been established, the prediction of actual N volatilization losses under a given set of soil and environmental factors can seldom be achieved due to the complex interactions (Bandel *et al.*, 1980).

Ammonia volatilization is intimately tied to soil pH near the fertilizer droplet or granule, which largely determines the ratio of NH_3 to NH_4^+ in the soil solution. The urease-mediated reaction of soil-applied urea with H_2O results in a rapid conversion to NH_4^+. In this reaction, H^+ ions are consumed and NH_4^+ and HCO^-_3 are produced, causing the soil pH at the reaction site to increase. The magnitude of increased pH is controlled in part by the H^+ buffering capacity (Ferguson *et al.,* 1984). Soils with a larger H^+ ion buffering capacity have been shown to also retain more NH_3 (Izaurralde *et al.*, 1990).

Approaches taken to decrease NH_3 loss include (i) the use of compounds that retard hydrolysis of urea by reducing the activities of urease which called urease inhibitors (Broadbent *et al.*, 1985; McCarty *et al.*, 1989; Al-Kanani *et al.*, 1994; Watson *et al.*, 2008); (ii) banding or incorporation of urea into the soil (Brydon, 1989 and Cambell *et al.*, 1990); (iii) mixing soluble salts with urea fertilizer such as potassium chloride, calcium chloride, triple superphosphate, or a mixture of these salts (Ouyang *et al.*, 1998; Fenn *et al.*, 1982), (iv) using slow released urea fertilizer forms such as sulfur-coated urea (Barsad *et al.*, 1999) and (V) using soil acidifying amendments (Stevensa *et al.*, 1992).

Elemental sulfur has been used for many years in the reclamation and improvement of sodic and calcareous soils (Hassan and Olson, 1966 and Abdel Fatah *et al.*, 1990). Recently, more attention is given to sulfur application to soils due to its favourable effects in promoting nutrient availability in soils (Saleh, 2001; Mostafa *et al.*, 1990 and El-Fakharani, 1996). In addition, sulfur is currently used to coat urea granules to increase its use efficiency by plants (Boswell and Friesen 1993).

Recovered sulfur production has become more significant as sour feedstocks are increasingly utilized and environmental laws on emissions and waste streams have continued to tighten worldwide. Recovered sulfur from petroleum refining industry increased from *5%* of the total production in 1950, to 67% in 1996. Discovery and development of large sour natural gas fields in many countries have also been important factors in this rapid growth. Increased processing of sour crude oil and tighter pollution control has caused most refineries to recover the sulfur content of its crude oil (Eow, 2002). Historically, sulfur recovery processes focus on the removal and conversion of hydrogen sulfide (H_2S) and sulfur dioxide (SO_2) to elemental sulfur (Chakma, 1997) as these compounds represent the largest source of potential sulfur emission. One of the recent sulfur recovery processes is a biological process (using H_2S oxidizing bacteria) for gas desulfurization and working at ambient temperatures and pressures (Cline *et al.*, 2003) and the sulfur product is, therefore, called THIOPAQ sulfur, as a trade name related to the PAQUES company owing the know how. One of the biggest unites of THIOPAQ sulfur recovery from sour natural gas is installed in Alexandria Mineral Oil Company (AMOC) near El-Maks area, Alexandria, Egypt, which is producing approximately 13 MT day^{-1} of elemental sulfur.

Application of elemental sulfur as an amendment for alkaline and/or calcareous soils had little attention as an inhibitor for ammonia volatilization. The objective of this work, therefore, was to evaluate the effects of elemental sulfur application rates to calcareous soils on ammonia volatilization from surface-applied urea fertilized soils and its influence on N uptake by corn (*Zea maize L.*)

MATERIALS AND METHODS

Incubation experiment:-

Laboratory experiments were conducted using three Aridisol soils (Calciorthids) from Abu Bakr and Adam at El-Noubaria region and Mostafa Ismail village at Bangar Essokar region representing the newly reclaimed lands in Egypt. Soil samples were collected from the surface layer (0–30 cm), air dried and ground to pass a 2-mm sieve. The main physical and chemical properties of the studied soils are given in Table 1.

Table (1): The main physical and chemical properties of the studied soils.

Property	Abu Bakr	Adam	Mostafa Ismail
Sand (%)	95.73	86.62	75.00
Silt + Clay (%)	4.27	13.38	25.00
Total $CaCO_3$ (%)	28.17	23.65	38.98
Organic Matter (%)	0.14	0.32	0.17
EC, dS m^{-1*}	8.85	10.01	2.50
pH$^{\#}$	8.48	8.22	8.60
Soluble cations (meq L^{-1}):			
Ca^{2+}	28.60	32.40	9.20
Mg^{2+}	15.80	32.60	5.40
Na^{+}	29.60	24.66	14.80
K^{+}	0.91	0.65	0.10
Soluble anions (meq L^{-1}):			
Cl^{-}	63.20	85.00	16.60
HCO_3^{-}	1.30	3.20	1.70
SO_4^{2-}	46.04	28.96	5.67

*** measured in soil saturated water extract**
 # measured in 1:2.5 soil-water suspension

A closed dynamic air flow system (Purakayastha and Katyal, 1998) was used to measure the NH_3 volatilization from the soils amended with urea or urea plus THIOPAQ elemental sulfur (TES). Triplicate samples of 150 g soil were thoroughly mixed with 0.5 (S1), 2.5 (S2) and 5.0 (S3) g TES particles (< 150 micron). The amount of distilled water needed to bring the soil to field capacity was added to each flask. The flasks were covered to prevent soil drying and allowed to incubate at room temperature for 24 h in order to re-establish soil microbial activity. Following the pre-incubation, urea fertilizer was evenly applied over the soil surface at a rate equivalent to 200 kg N ha^{-1} on an area basis. Each flask was connected to an air flow system immediately after the fertilizer application and the outlet tube from each flask was immersed in 2% boric acid-mixed indicator solution to capture the NH_3 volatilized from soil surface (Al-Kanani *et al.*, 1994). Before reaching the soil chambers, the compressed air flow was first passed and bubbled through distilled water to dissolve extraneous sources of NH_3 and to produce humidified air. The air flow through the soil chambers was maintained at a rate equivalent to 12 volume exchanges per min. The boric acid-mixed indicator traps were replaced every 24 h for a period of 30 days and NH_3-N evolved was determined by titration (Bundy and Meisnger, 1994). The amounts of volatilized NH_3-N were calculated as percent of urea-N applied. At the end of experimental period, the pH in soil suspensions (1:2.5 soil : water) and SO_4^{2-} concentration in saturation extracts of soil paste were determined. Sulfate was measured using ICP-AES Thermo 6000 series.

Greenhouse experiment

The effect of TES application in combination with nitrogen fertilizer on plant growth and nitrogen uptake by zea maize was conducted under greenhouse conditions. In a pot, at first 3.80 kg soi, which collected from Adam Village was plac followed by about 500 ml water, then1.00 kg soil, which contains the basal nutrients (800 mg N + 500 mg P + 900 mg K) and sulfur, was added to the pots then the soil was saturated with about 130 ml water. Ten seeds of corn (cv: hybrid single 110) were distributed over the soil surface then covered by about 200 g soil. Sulfur application was added in 4 rates: 0 (S0), 0.615 (S1), 3.08 (S2) and 6.15 g pot^{-1} (S4) which represent 0.00, 0.1, 0.5 and 1.0 ton ha^{-1}. Sulfur-oxidizing bacteria *Thiobacillus thiooxidans* were added to the soil at a rate of 10 ml pot^{-1} (each ml contains $1x10^6$ cfu) after carrying it on 50.0 g peat moss and mixed with the soil mixture and then were transferred on to the soil in the pot.

After preparing the pots, they were weighed and arranged in the greenhouse in a randomized complete design. The pots were placed on a scale daily and water was applied to reach their original weight. After 10 days of emergence, the growing seedlings were thinned to five strongest ones. After 10 and 17 days, 300 mg N were added to each pot.

After 40 days of submergence, plants were withdrawn and the fresh weight of the whole plant, shoot and root was recorded. The plants were then washed with tap water then by distilled water then were oven-dried at 70°C for 24 hrs, weighed and crushed. The total nitrogen content in the oven-dried plant material was determined in both roots and shoots using Kjeldahl digestion and distillation methods (Baker and Thompson, 1992).

The data obtained were statistically analyzed and the analysis of variance for the results were obtained by the program of Costat software (Costat, 1985).

RESULTS AND DISCUSSION

Ammonia volatilization

The results of daily NH_3-N volatilization (loss as % of applied N) from surface–applied urea (U) and amended urea with different rate of TES (U, U+S1, U+S2 and U+S3) to Abu Bakr, Adam and Mostafa Ismail soils are shown in Fig. 1. The ammonia loss per day was the highest at day 26 with urea and amended urea with TES in Abu Bakr soil, while it reached peak rates at day 10 with urea and day 5 with amended urea with TES in Adam and Mostafa Ismail soils, respectively. The peak rates of NH_3 volatilization from amended urea with TES were strikingly lower than that of the un-amended urea, particularly in Adam and Mostafa Ismail soils. The maximum volatilization rate from urea and amended urea with TES for the different soils are being in the order: Mostafa Ismail > Abu Bakr > Adam. This order was related to $CaCO_3$ content in the studied soils.

The cumulative NH_3-N loss from urea and amended urea with different rates of applied TES to the three tested soils is shown in Fig.2. The results showed that the cumulative NH_3-N loss started gradually to increase after 2 days from fertilizer application until the end of incubation period with urea in the three tested soils, and with urea amended with TES in Abu Bakr soil. However, it was lower for the amended urea with TES than for the un-amended urea throughout the experimental period, particularly in Adam and Mostafa Ismail soils. In the urea-treated soils, it was observed that the order of cumulative N losses were Mostafa Ismail> Adam> Abu Bakr within the first 18 days of incubation (Fig. 2), then were in the order Abu Bakr > Adam> Mostafa Ismail until the end of the experiment (30 days).

The effect of amended urea, with different rates of TES, on total NH_3 volatilization loss and is shown in Table 2. The total NH_3 volatilization from urea-treated soils were 50.32, 49.76 and 66.56 % in Abu Bakr, Adam and Mostafa Ismail soils, respectively. Significant reductions in NH_3 volatilization were observed in urea amended with TES and this reduction increased by increasing TES rate. The percentage inhibition in NH_3 loss as a result of application of different rates of TES ranged between 14.60-37.52, 75.28–84.52 and 70.00 – 77.42 in Abu Bakr, Adam and Mostafa Ismail soils, respectively.

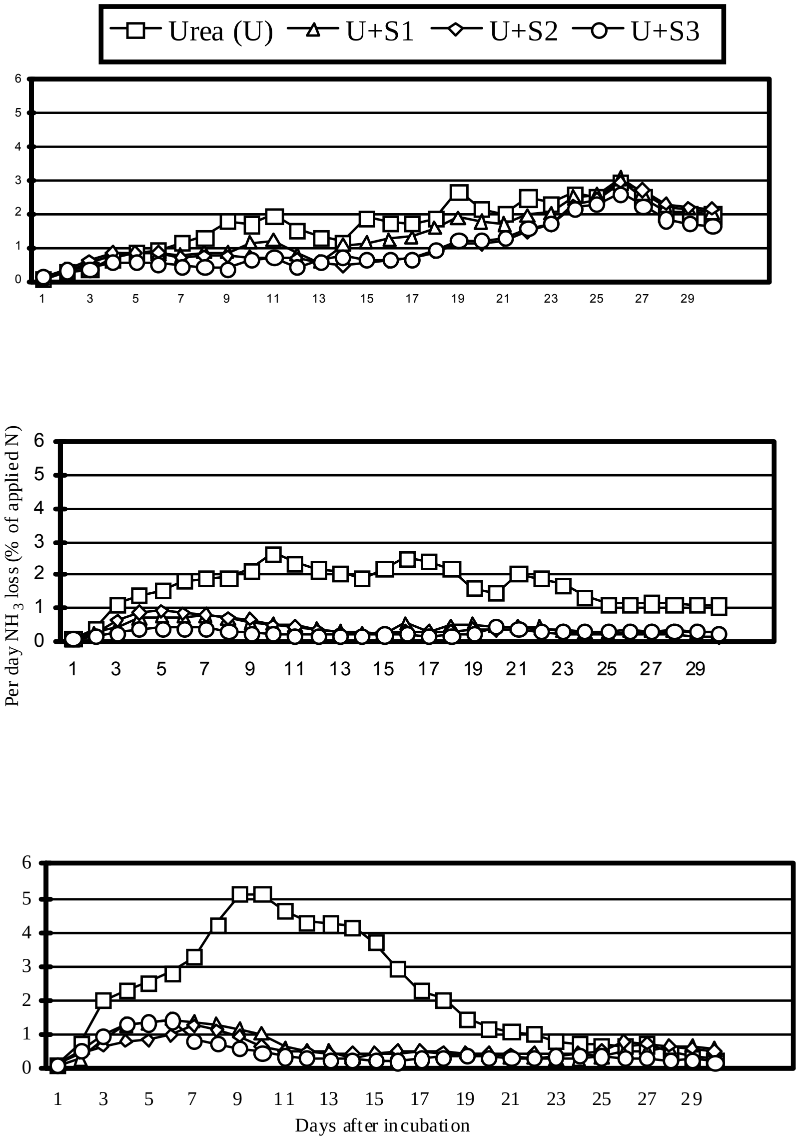

Fig. 1 Effect of THIOPAQ sulfur application on the daily NH3-N loss by volatilization from surface-applied urea treated soils from Abu Bakr, Adam and Mostafa Ismail villages..

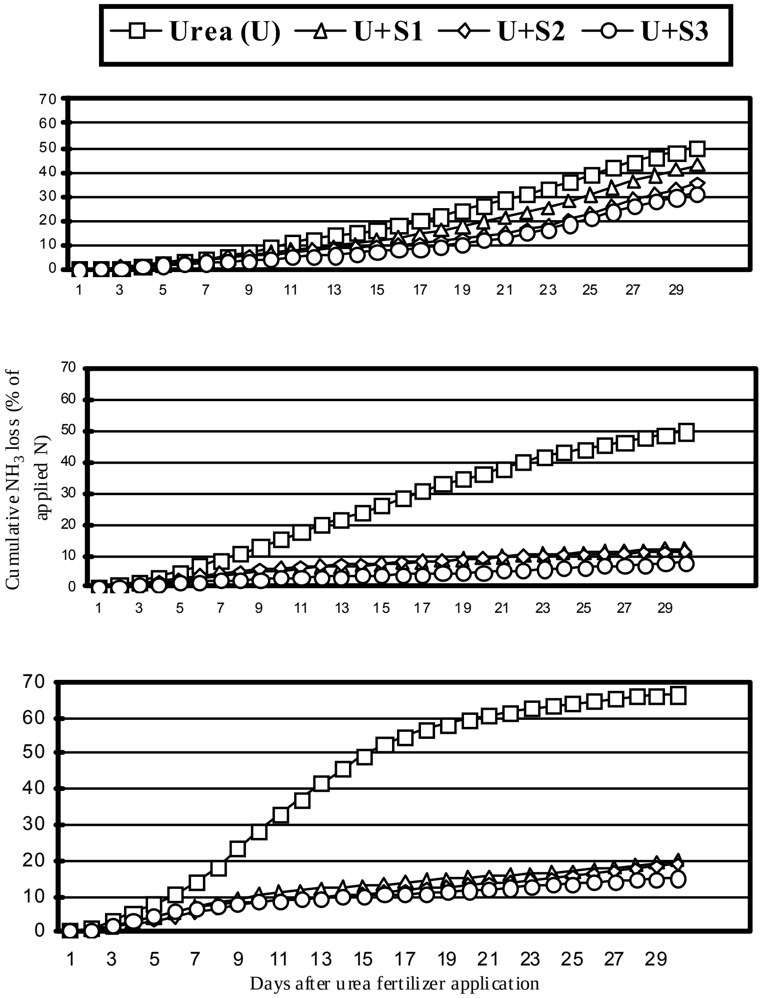

Fig. 2. Effect of THIOPAQ sulfur application on cumulative NH_3-N loss by volatilization from surface-applied urea treated soils from Abu Bakr, Adam and Mostafa Ismail villages.

The effect of amended urea with different rates of TES on the changes in the pH and sulfate concentration of the tested soils after 30 days of incubation are shown in Table 3. Application of TES significantly reduced the soil pH and increased SO_4^{2-} concentration in the three tested soils. The soil pH was reduced by values ranged between 0.36 - 0.63, 0.28-0.47 and 0.21-0.39 pH unit in Abu Bakr, Adam and Mostafa Ismail soils, respectively.

Table 2: Effect of amended urea with different rates of TES (S1=100, S2=500 and S3= 1000 kg S ha^{-1}) on total NH_3-N volatilization loss and its inhibition in Abu Bakr, Adam and Mostafa Ismail soils.

Treatment	NH_3-N loss (% of N applied)			% inhibition[a]		
	Abu Bakr	Adam	Mostafa Ismail	Abu Bakr	Adam	Mostafa Ismail
Urea (U)	50.32	49.76	66.56	-	-	-
U + S1	42.96	12.30	19.97	14.60	75.28	70.00
U + S2	35.99	11.11	18.86	28.48	77.67	71.66
U + S3	31.44	7.70	15.03	37.52	84.52	77.42
LSD(*p*=0.05)	2.95	2.82	2.89	-	-	-

[a:] Percentage inhibition = (A – B)/A x 100 where A and B stand for loss from urea and amended urea fertilizers, respectively

Table 3: Effect of amended urea with different rates of TS (S1=100, S2=500 and S3= 1000 kg S ha^{-1}) on the changes in pH of soil suspension and sulfate concentration in saturation extracts of Abu Bakr, Adam and Mostafa Ismail soils after 30 days of incubation.

Treatments	pH			SO_4^{2-} (mg kg^{-1})		
	Abu Bakr	Adam	M.Ismail	Abu Bakr	Adam	M.Ismail
Urea (U)	8.28	8.12	8.14	734.71	392.30	89.25
U+S1	7.92	7.84	7.93	1156.64	1515.68	751.18
U+S2	7.75	7.65	7.83	1254.95	1940.65	812.86
U+S3	7.66	7.65	7.75	1653.99	2161.22	1061.65
LSD(*p*=0.05)	0.21	0.19	0.23	24.91	23.06	27.03

Nitrogen uptake by corn

The pot experiments carried out under greenhouse conditions showed that application of TES with urea-N fertilizer had significant effect to enhance the N uptake by corn plants. Table (4) presents the total uptake of nitrogen by plant roots and shoots. Nitrogen is considered the major macronutrient required by plants from the early growth stages and its translocation to the upper parts starts sooner after N uptake by plant roots. Therefore, its concentration in the plant shoots of corn always higher than in the plant roots (Table 4). Soil inoculation by *T. thiooxidans* without any addition of S increased the N concentration in both shoots and roots (22.25 and 19.5%, respectively, more than those occurred in the control treatment).

Application of elemental sulfur markedly increased nitrogen uptake by both plant shoots and roots (Table 4). Nitrogen content in plant shoots increased by about 24.14, 51.55 and 60.87% in S1, S2 and S3-treated soils relative to in the control treatment and in the plant roots were 29.79, 27.84 and 31.12%, respectively, relative to the control treatment (Table 4). Application of S and S-oxidizing bacteria together in the soil resulted in more increase in N uptake in both shoots and roots of plant as compared with only S-treated or bacteria-treated soils.

Figure (3) summarizes the results of total N uptake by corn plants as a function of S application rate and inoculation with S-oxidizing bacteria (*T. thiooxidans*). In general, without bacterial inoculation, applied S by the rates of 0.5 and 1.0 t ha^{-1} significantly increased the total N uptake by corn plants comparing with the control or S1 (0.1 t ha^{-1})-treated soils. On the other hand, there were marked differences in the uptake in the plants treated with S2 and S3. Soil inoculation by *T. thiooxidans* showed that total N uptake by plants grown in soils treated with S1 and S2 was increased more than that obtained with S3-treated soil (Fig. 3). Also, the results of N uptake from the soil treated with S1+inoculants were more than those monitored in all three rates of applied S. In addition, we can report from Fig. 3 that the role of *T. thiooxidans* is negligible in the soils amended with 1.0 t S ha^{-1}.

Table (4): The fresh and dry weights and N uptake in shoot and root of corn plants after 40 days of submergence as influenced by sulfur and *T. thiooxidans* inoculation.

Treatments	Fresh Weight (g pot^{-1})	Dry Weight (g pot^{-1})		N uptake (mg pot^{-1})	
	total plant	shoot	root	shoot	root
Soil +S0	90.74	9.49	2.47	403.53	87.79
Soil + S1	82.34	11.19	2.89	500.95	113.94
Soil + S2	123.67	14.87	3.23	611.53	112.14
Soil + S3	156.32	14.58	3.64	649.17	112.14
Soil + S0 + Bacteria	102.58	9.69	2.56	493.31	104.91
Soil + S1 + Bacteria	139.71	14.52	3.69	717.43	129.05
Soil + S2 + Bacteria	160.73	16.19	4.75	775.76	154.54
Soil + S3 + Bacteria	150.39	14.54	3.99	684.94	139.04

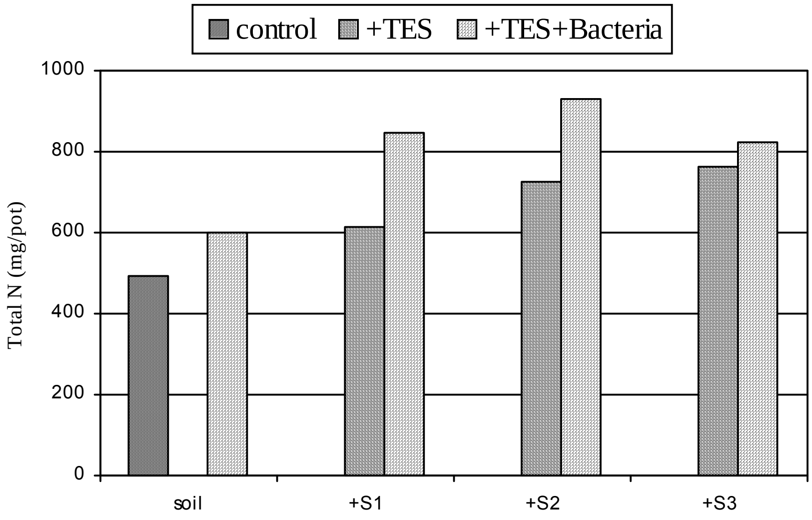

Fig. (3): Effect of THIOPAQ sulfur (TES) application rates to Adam soil on the total uptake of nitrogen by 40-day old corn plant grown under greenhouse conditions in the absence and presence of sulfur oxidizing bacteria.

Results of N uptake by corn were similar to previous studies. Chaubey *et al.* (1993) found increases in N uptake by linseed grains and straw as a result of S application to the sandy loam soils. Singh and Chaudhari (1995) recorded higher concentrations of N in tissues of peanut plants grown on calcareous soils with applied S compared to those without S.

The reduction of NH_3-N volatilization obtained, in this study, as a result of TES application with urea-N fertilizer might be due to neutralization of the alkaline urea microsites by the H_2SO_4 generated by TES upon oxidation (Blaise and Prasad 1995). Under aerobic conditions and in the presence of moisture, sulfur undergoes oxidation, producing H_2SO_4 and then the acidic environment in the soil (low pH) favors the conversion of NH_3 to NH_4^+ and thus suppresses NH_3 volatilization (Fenn and Hossner 1985).

In the current study, soils response to applied sulfur in reducing NH_3 volatilization, from surface urea-N received soils markedly differed; with respect highly and moderately $CaCO_3$ content in soils such as which are used in the current study. It is found that S application strongly inhibits the hydrolysis process of urea even with the lowest rate of applied S (0.1 ton ha^1). The concentration of native soil water soluble sulfate is another observation can play a role in the influence of TES application on NH_3 volatilization from soil surface. It seems that the high concentration of SO_4^{2-} in soil solution occurred in Abu Bakr soil (46.04 meq L^{-1}) retarded or inhibited the process of sulfur oxidation. It is obvious that SO_4^{2-} is one of the end products of the biological S oxidation reaction (Schippers *et al.*, 1996). Therefore, increasing one of the end products in soil solution might inhibit the oxidation process. One of the confirming indicators was the released of SO_4^{2-} to the soil solution as a result of TES application (Table 3), where more SO_4^{2-} released as the concentration of native soil SO_4^{2-} decreased.

The present study showed highly significant effects of THIOPAQ sulfur (TES) application and/or S-oxidizing bacterial inoculation on biomass production and N uptake by corn plants (Table 5). Increasing of N uptake by inoculated plants in the absence of applied TES (S0) indicated to some roles of inoculants such as releasing or exudation of growth promoting substances or nitrogen uptake stimulators in the rhizosphere. However, these suggestions need further investigations under more controlled conditions.

It can be concluded, therefore, that application of S by the rate 0.5t ha^{-1} to the corn plants grown on calcareous soil can be recommended for increasing N use efficiency. However, this recommendation also requires some verification tests under field conditions.

Table (5): Two-way ANOVA significance levels of the effects of sulfur application and *T. thiooxidanse* bacteria on the mean of fresh and dry weight and total N uptake by corn plants. at *p< 0.05, **p< 0.01, ***p<0.001or n.s. not statistically significant.

Factors	Measured Variables			
	Fresh Weight	Shoot DW	Root DW	Total N
Sulfur (S)	***	***	***	***
Bacteria (B)	***	ns	**	**
Interactions	**	ns	ns	ns

REFERENCES

Abd-Elfattah, A., M.H. Hilal, K.M. El-Habbasha and M.D. Bakry. 1990. Amendment of Alkaline clay soil by elemental sulfur and its effect on the response of garlic to phosphorus and nitrogen. In: Proceedings Middle East Sulfur Symposium, 12-16 Feb. 1990. Cairo, Egypt. 295-313.

Al-Kanani, T., A.F. Mackenzie, J.W. Fyles, S. Ghazala and I.P. O'Halloran.1994. Ammonia volatilization from urea amended with lignosulfonate and phosphoroamide. Soil Sci. Soc. Am. J. 58: 244-248.

Baker, W.H. and T.L. Thompson. 1992. Determination of Total Nitrogen In Plant Samples by Kjeldahl. In: C.O. Plank (ed). Plant analysis reference procedures for the Southern Region of the United States. SCSB no. 368.

Blaise D, R. Prasad. 1995. Effect of blending urea with pyrite or coating urea with polymer on ammonia volatilization loss from surface-applied prilled urea. *Biology and Fertility of Soils* 20, 83-85.

Boswell CC and D.K. Friesen. 1993. Elemental sulfur fertilizers and their use on crops and pastures. Fertilizer Res. 35, 127-149.

Broadbent, F.E., T. Nakashima and G.Y. Chang.1985. Performance of some urease inhibitors in field trials with corn. Soil Sci. Soc. Am. J. 49: 348-351.

Bundy, L.G. and J.J. Meisinger. 1994. Nitrogen availability indices, pp 951-984. In Weaver (ed.) "Methods of Soil Analysis, Part 2: Microbiological and biochemical properties" Book Series no. 5, Soil Sci. Soc. America. Mad. WI., USA.

Purakayastha, T.J. and J.C. Katyal. 1998. Evaluation of compacted urea fertilizers prepared with acid and non-acid producing chemical additives in three soils varying in pH and cation exchange capacity: I. NH3 volatilization. Nutr Cycl Agroecosyst 51:107–115.

Byrnes, B.H. and J.R. Freney. 1995. Recent Developments on the use of urease inhibitors in the tropics. Fertilizer Res. 42: 251-259.

Cambell, C.A., J.G. Mcleod, F. Selles, F.B. Dyck, C. Vera and D.B. Fowler. 1990. Effect of rate, timing and placement of N fertilizer on stubbled-in wheat grown on a brown Chernozem. Can.J. Plant Sci. 70: 151-162.

Chakma, A. 1997. Acid Gas Re-injection: A Practical Way to Eliminate CO_2 Emissions from Gas Processing Plants. Energy Convers. Mgmt., 38:S205-S209.

Chauby, A. K., K.N. Dwivedi, M. Buddesh, and B. Mani. 1993. Response of linseed to N and S fertilization in alluvial soil of central region of U.P. Indian J, Agric. Chem., 26 (2-3): 91-96.

Cline, C., A. Hoksberg, R. Abry and A. Janssen. 2003. Biological process for H2S removal from gas streams: The Shell-Paques/ ThiopaqTM gas desulfurization process. LRGCC, 23-23 February, 2003. Norman, Oklahoma, USA.

Costat. 1985. User's Manual. Version 3, Cohort. Tusson, Arizona, USA.

El-Fakharani, Y.M. 1996. Salt tolerance of wheat irrigated with saline water in a sandy soil as affected by sulphur and organic manure. J. Agric. Sci., Mansoura Univ., 21, 2805-2819.

Eow, J.S. 2002. Recovery of Sulfur from Sour Acid *Gas:* A Review of the Technology. Environ. Progress, 21 (3): 143-162.

Fenn LB, Hossner IR (1985) Ammonia volatilisation from ammonium or ammonium forming nitrogen fertilizers. *Advances in Soil Science* 1, 771-776.

Fenn, L.B., J.E. Matocha, and E.Wu. 1982. Substitution of ammonium and potassium for added calcium for reduction of ammonia loss from surface applied urea. Soil Sci. Soc. Am. J. 46: 771-776.

Ferguson R B, Kissel D E, Koelliker J K and Basel W 1984 Ammonia volatilization from surface-applied urea: Effect of hydrogen ion buffering capacity. Soil Sci. Soc. Am. J. 48, 578-582.

Flower, D.B., and J. Brydon. 1989. No-till winter wheat produced on Canadian Prairies: Placement of urea and ammonium nitrate fertilizer. Agron. J. 81: 518-524.

Hassan, N. and R.A. Olson. 1966. Influence of Applied Sulfur on Availability of Soil Nutrients for Corn (Zea mays L.) Nutrition. Soil Science Society of America Journal. 30: (2): 284-286.

Gould, W.D., C. Hagedorn and R.G. McCready. 1986. Urea Transformations and Fertilizer Efficiency in Soil. Advances Agron. 40: 209-238.

Heffer, P. and M. Prud'homme. 2009. Short-term fertilizer outlook 2009-2010. in "IFA 35th Enlarged Council Meeting, Amman, November 2009.

Izaurralde R.C., Y. Feng, J.A. Robertson, W.B. McGill, N.G. Juma and B.M. Olson. 1995. Long–term influence of cropping systems, tillage methods, and N sources on nitrate leaching. Can. J. Soil Sci. 75: 497–505.

McCarty, G.W., J.M. Bremner and H.S. Chai. 1989. Effect of N-(n-butyl) thiophosphoric triamide on hydrolysis of urea by plant, microbial and soil urease. Biol. Fert. Soils 8: 123-127.

Mostafa, M.A., A.M. Elgala, M.M. Wassif and S.E. El-Maghraby. 1990. Distribution of some micronutrients through a calcareous soils column under saline water application. In: Sulfur in Agricultural Soils. Proceedings of the International Symposium, Dhaka, April 2-22, 1986: 263-276.

Nelson, D.W. 1982. Gaseous losses of nitrogen other than through denitrification. In F.J. Stevenson (ed) "Nitrogen in Agricultural Soils" Agron. Monograph no. 22. ASA-CSSA-SSSA, Mad. WI., USA.

Ouyang, D.S., A.F. Mackenzi and M.X. Fan. 1998. Ammonia volatilization from urea amended with triple superphosphate and potassium chloride. Soil Sci. Soc. Am. J. 62: 1443-1447.

Parsad, R., D.K. Singh, R.K. Singh and A. Rani. 1999. Ammonia volatilization loss in rice-wheat cropping system and ways to minimize it. Fertilizer News. 44: 55-56.

Saleh, M.E. 2001. Some agricultural applications for biologically-produced sulfur recovered from sour gases. I. Effect on soil nutrients availability in highly calcareous soils. In "International Symposium on Elemental Sulfur for Agronomic Application and Desert Greening" United Arab Emirates University, Abu Dhabi, UAE, Feb. 24-25, 2001.

Schippers, A., Jozsa, P.G. and W. Sand. 1996. Sulfur Chemistry in Bacterial Leaching of Pyrite. Applied Environ. Microbiol. vol. 62 (9): 3424–3431.

Singh, A.L. and V. Chaudhari. 1995. Source and mode of sulphur application on groundnut productivity. J. Plant Nutr. 18 (12): 2739 – 2759.

Stevensa, R.J., R. J. Laughlinal and J.P. Frosta. 1992. Effects of Separation, dilution, washing and acidification on ammonia volatilization from surface-applied cattle slurry. The J. Agri. Sci., 119: 383-389.

Watson, C. J., N. A. Akhonzada, J. T. G. Hamilton and D. I. Matthews. 2008. Rate and mode of application of the urease inhibitor N-(n-butyl) thiophosphoric triamide on ammonia volatilization from surface-applied urea. Soil Use and Manag., 24: 246–253

استخدام كبريت الثيوباك لخفض تطاير الأمونيا من الأراضي الجيرية وزيادة كفاءة استخدام النيتروجين بواسطة نباتات الذرة

أمل حسن محمود و خميس عبد العزيز راتب
معمل بحوث الأراضي الملحية والقلوية – معهد بحوث الأراضى والمياه والبيئة – اسكندرية

من خلال التجارب المعملية وتجارب الصوبة تم تقييم تأثير إضافة معدلات مختلفة (٠,١، ٠,٥، ١,٠ طن للهكتار) من كبريت الثيوباك مع سماد اليوريا المضاف الى الأراضي الجيرية (بمعدل ٢٠٠ كجم نيتروجين للهكتار) على معدل تطاير النيتروجين من سطح الأرض فى صورة أمونيا وعلى كفاءة امتصاص النيتروجين بواسطة نباتات الذرة النامية تحت ظروف الصوبة لعمر ٤٠ يوم.

تحت ظروف المعمل تم تتبع التطاير اليومى للأمونيا من سطح الأرض المحضنة فى دوارق مخروطية فى نظام ديناميكى مغلق يستمر فيه احلال الهواء المتجمع أعلى سطح الأرض والمحمل بالأمونيا بهواء مدفوع الى الدوارق. وقد اوضحت النتائج أن المعدلات اليومية للأمونيا المتطايرة كانت فى أرض مصطفى اسماعيل أكبر من أرض آدم وهذه أكبر من أرض أبوبكر خلال ال١٨ يوم الأولي من التحضين ثم تحول هذا الترتيب فى باقى الأيام لتكون فى أبو بكر أكبر من آدم وهذه أكبر من مصطفى اسماعيل. وكانت الكميات الكلية المتطايرة خلال ال ٣٠ يوم تمثل ٥٠,٣ ، ٤٩,٨ و ٦٦,٦% من اليوريا المضافة فى أبوبكر وآدم و مصطفي اسماعيل على التوالى. وقد حدث نقص معنوى فى الأمونيا المتطايرة نتيجة إضافة كبريت الثيوباك بنسب تراوحت من ١٤,٦ – ٣٧,٥ فى أرض أبوبكر ومن ٧٥,٢٨ – ٨٤,٥٢ فى آدم ومن ٧٠,٠ – ٧٧,٤٢ فى أبوبكر. وقد صاحب ذلك انخفاض فى pH الأرض وزيادة فى تركيزات انيون الكبريتات فى المحلول الأرضي. وقد خلصت تجارب تطاير الأمونيا الى أن إضافة كبريت الثيوباك بمعدلات ١٠٠ كجم و ٥٠٠ كجم للهكتار كان لها تأثيرات معنوية على خفض التطاير من سطح الأرض المسمدة باليوريا.

وقد أوضحت نتائج الزراعة فى الصوب أن إضافة الكبريت مع التلقيح ببكتريا أكسدة الكبريت *T. thiooxidans* كان له تأثير إيجابي معنوى على وزن النبات وعلى امتصاص النيتروجين فى كل من المجموع الخضرى (بزيادة قدرها ٢٢,٢٥%) والجذرى (بزيادة قدرها ١٩,٥٠%) لنباتات الذرة. وقد أظهرت النتائج الدور التحفيزى للبكتريا بمفردها فى زيادة امتصاص النيتروجين.

قام بتحكيم البحث

أ.د / أحمد عبد القادر طه	**كلية الزراعة – جامعة المنصورة**
أ.د / ابراهيم حسين السكرى	**كلية الزراعة – جامعة الأسكندرية**